Multimodal mixed reality interfaces for visualizing digital heritage

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Martin White*, Panagiotis Petridis*, Fotis Liarokapis+, Daniel Plecinckx*,

* University of Sussex, Department of Informatics
Centre for VLSI and Computer Graphics, Falmer, BN1 9QT, UK
p.petridis@sussex.ac.uk, m.white@sussex.ac.uk

+ City University, Department of Information Science
giCentre, London EC1V 0HB, UK
fotisl@soi.city.ac.uk

*Visual Dimension, Ename, B-9700, Belgium
daniel.pletinckx@visualdimension.be

Abstract

We have developed several digital heritage interfaces that utilize Web3D, virtual and augmented reality technologies for visualizing digital heritage in an interactive manner through the use of several different input devices. We propose in this paper an integration of these technologies to provide a novel multimodal mixed reality interface that facilitates the implementation of more interesting digital heritage exhibitions. With such exhibitions participants can switch dynamically between virtual web-based environments to indoor augmented reality environments as well as make use of various multimodal interaction techniques to better explore heritage information in the virtual museum. The museum visitor can potentially experience their digital heritage in the physical sense in the museum, then explore further through the web, visualize this heritage in the round (3D on the web), take that 3D artifact into the augmented reality domain (the real world) and explore it further using various multimodal interfaces.

1. INTRODUCTION

Modern cultural heritage exhibitions have evolved from static exhibitions to dynamic and challenging multimedia explorations. The main factor for this has been the domination of the world-wide web, which allows museums and other heritage exhibitions to be presented and promoted online. Museum virtual environments can offer much more than what many current museum web sites offer. A typical example is a catalogue of pictures with metadata displayed in a web browser, and perhaps an image one can zoom into and out of. Digital artifacts or cultural objects can, however, be presented in a virtual museum and viewed in the round. A virtual museum can consist of many exhibitions representing different museum collections.

In a more interactive experience, users can select some cultural objects and observe their digital representations in the context of real artifacts, for example in an augmented reality (AR) scene.

In recent years Mixed Reality (MR) has emerged as an area of extreme interest for visualizing and interacting with three-dimensional (3D) information in context, while the cost of building suitable MR applications has fallen considerably. Mixed reality interfaces, interaction techniques and devices are developing at a rapid pace and offer many advantages over traditional windows style interfaces. In 1994, Milgram [1] tried to depict the relationship between virtual and augmented reality by introducing two new terms called mixed reality (MR) and augmented virtuality (AV). We aim to explore this mixed reality and augmented virtuality space with our system.

Virtual museums that exploit both MR and VR can offer much more interesting interactive scenarios for viewing their digital collections (virtual reconstructions of their actual artifacts). VR interfaces, interaction techniques and devices are developing very rapidly and offer many advantages for museum visitors. For example, many interaction devices are now available that can be integrated into multi-modal virtual and augmented reality interactive interfaces [2]. These technologies can be integrated with cheap but powerful PC desktop systems as well as bespoke museum kiosks. A major advantage of using cheap and powerful PCs is that they can be easily re-purposed with new virtual exhibitions.

It is important that the use of MR technologies in virtual museum exhibitions or tours does not just present virtual objects and descriptions, i.e. a 3D replacement to the traditional museum website; they must be set in a story that reinforces the visitors learning and understanding of the cultural content. Museums are one of the best places to exploit these virtual technologies [3] because they offer challenging research opportunities, while providing novel ways to present regional or national heritage, as well as offering new consultation methods for archaeological or cultural sites and museums [4].

1.1. Background Work

In the past a number of experimental systems have been proposed for museum environments. Many museum applications based on VRML have been developed for the web [5-7]. A more interactive concept is the Meta-Museum visualized guide system based on AR, which tries to establish scenarios and provide a communication environment between the real world and cyberspace [3].

In addition, a number of EU projects have been undertaken in the field of virtual heritage. There are many ways where archaeological data sources can be used to provide a mobile AR system. The SHAPE project [8] tries to combine MR technologies with archaeology to enhance the interaction of persons in public places like galleries and museums. The system aims in educating the visitors about artifacts and their history. The 3DMURALE project developed 3D multimedia tools to record, reconstruct, encode and visualize archaeological ruins in virtual reality using as a test case the ancient city of Sagalassos in Turkey. These tools are applied to buildings, building parts, statues, stratigraphy, pottery, terrain geometry, textures and texture materials [9].

The Ename 974 project developed a non-intrusive interpretation system to convert archaeological sites into open-air museums, called TimeScope-1 [10]. The architecture is based on 3D computer technology originally developed by IBM, called TimeFrame. The visitors enter a specially designed on-site kiosk where real-time video images and other architectural reconstructions are superimposed into the monitor screens. The ARCHEOGUIDE project [11] provides an interactive AR guide for the visualization of archaeological sites. The system is based on mobile computing, networking and 3D visualization providing the users with a multi-modal interaction user interface. Another project that uses AR technologies is LIFEPLUS [12], which explores the potential of AR so that users can experience a high degree of realistic interactive immersion. However, a fundamental difference is that it allows the rendering of realistic 3D simulations of virtual humans, animals and plants in real-time.

The PURE-FORM project developed two systems that will allow the visitor to appreciate every aspect of a 3D art piece not by simply staring at a distance but by touching it [13]. The first system is located in a museum in a kiosk around real artifacts. The idea behind this implementation is that anyone visiting the museum will be able to normally observe the displayed art collection and on top of that will be able to use a haptic interface developed within the project to interact with a digital representation of a real museum artifact displayed on a screen next to the artifact. The second system is located in a gallery-like environment such as the CAVE system, containing a set of digital representation of selected sculptures in a virtual environment and the user will be able to navigate in that environment, select a sculpture and interact through the use of the haptic interface.

The ART-E-FACT project proposed that the use of a semantic web can enable the learning institutions to make their cultural content available to researches, curators or public in a meaningful way [14]. ART-E-FACT acknowledged the fact that the use of digital storytelling and MR technologies will create a new dimension for artistic expression. The project created a platform for developing and exploring new forms of creation, presentation and interaction as well as tools for 3D content generation [15]. The system is composed of a story telling engine that controls the virtual environment with virtual characters that interactively presents a work of art, the rendering engine, the authoring tool which defines the story (presentation) and is connected to the database, the database contains information about the cultural objects, a gesture recognition system that detects hand gestures and infrared markers on dedicated objects.

2. VIRTUAL MUSEUM REQUIREMENTS

We can set out a few simple requirements that a visitor may find useful when interacting with a virtual museum exhibition. We take as a start the scenario where the visitor is in the museum and can see the physical artifact in its glass case, but wishes to explore further, i.e. visitor wishes to see the artifact in the round, get behind it and underneath it. From this basic scenario we can construct a simple user requirement list, see Table 1.

Table 1: User Requirements.

URs	**Description**
UR1	Users should be able to explore the artifact further in a museum web base interactive environment.
UR2	Users should be able to explore the artifact further in a museum physical interactive environment
UR3	Users should be able to explore the artifact in the round (i.e. turn, translate, etc.)
UR4	Users should be able to explore the through tactile feel as well as sight
UR5	User should be able to feel a representation of the surface texture of the artifact.
UR6	User must be able to access information about the artifact from the interface in appropriate multimedia formats, e.g. text, audio, 3D, movies, etc.
UR7	User may not touch the actual physical artifact.

Given these basic requirements we can first introduce a novel multimodal mixed reality system and then explore the requirements illustrated in Table 1 though different scenarios.

3. A MULTIMODAL MIXED REALITY INTERFACE

A multimodal mixed reality interface can be exploited to provide several different and interesting types of virtual heritage exhibitions. The novelty of the technologies employed is that they allow users to switch between three different types of visualization environments including: the web in the traditional way, but including 3D, virtual reality and augmented reality (thus mixing these different formats into the same architecture). Additionally, several different interface techniques can be employed to make exploration of the virtual museum that much more interesting. A high-level diagram illustrating the technologies employed in the multimodal mixed reality system is presented in Figure 1. Here, we can see there are several interaction modes from use of SpaceMouse and gamepad through to use of a physical replica of an artifact, and simple hand manipulation of AR marker cards. We can also see several visualization scenarios from the familiar web page but with 3D object, a virtual gallery environment, a person using a physical replica of an artifact to control and explore the virtual artifact, and several AR examples.

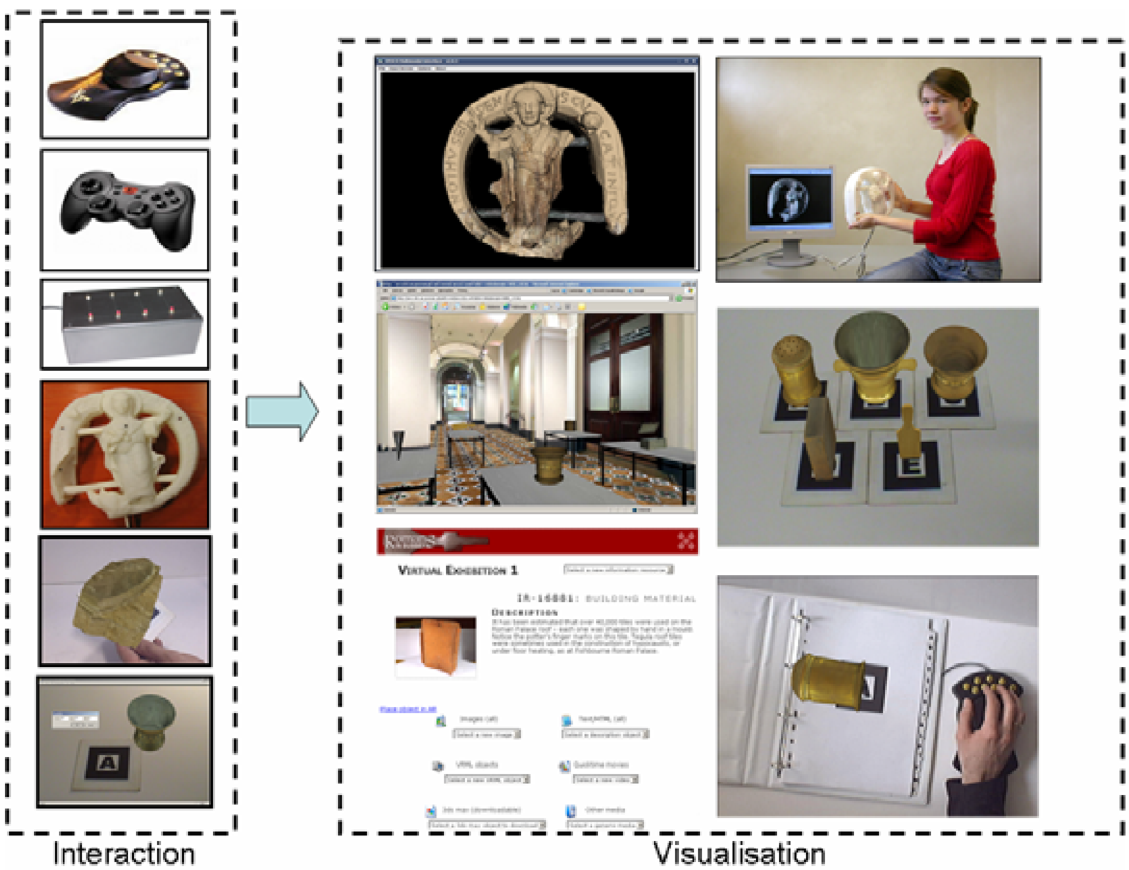

Figure 1: Multimodal mixed reality interface

The proposed multimodal mixed reality interface allows users to select the best visualization mode for a particular application scenario. The basic idea behind this is based on the concepts of two previously implemented separate interfaces: a multimodal interface for safely visualizing museum artifacts [16-18] and a mixed Web/AR for virtual museums [16-18]. The integration of these two interfaces allows users to transfer 3D information (3D artifacts and metadata) over the internet and superimpose them on an indoor AR environment as well as interact with the artifacts in a number of different ways using several types of interaction device. Integrating the two systems together can easily be achieved by treating them as two separate but communicating interfaces; all that is needed is a method to transfer data between the two interfaces.

EXtensible Markup Language (XML) was originally designed to describe data but during the last years XML has become a standard for implementing data communication over the Internet. Two approaches can be taken: develop your own protocol or use a standard based on XML such as SOAP as a message passing service. Either way, using XML, data can be easily exchanged between incompatible systems. We used the Xerces-C++ validating XML parser [19] which was easily integrated into our AR application and used to directly parse XML files (our XML files contained essentially the graphical content and structure of the virtual exhibition).

The virtual exhibition examples shown in Figure 1 based on the original Web/AR application has the exhibition structured in an XML repository which contains metadata, digital content and exhibition parameters. This XML repository [20] or XML format can be parsed by different visualization applications provided they have the appropriate parser. Our Web/AR environment utilizes OpenVRML and OpenGL and to visualize 3D digital content in the XML repository on the Web and in the AR environment respectively [21, 22].

4. DIGITAL HERITAGE VISUALIZATION

The visualization of digital content in our system exploits three presentation domains that are loosely integrated; it is possible to build a system combined of all three or any one:

- A Web3D domain.
- A virtual environment domain.
- An augmented reality domain.

4.1. Web3D Example

The great benefit of Web3D technologies is that it offers tools for creating virtual environments using technologies like VRML and X3D, which are essentially scene graph languages that allow us to create 3D scenes or virtual environments on the web. This allows us to further blend 3D with other multimedia content on the web. Consequently, Web3D has the potential to be applied to a number of different application scenarios [21], and in this work we use it to provide the web client for our visualization interfaces (i.e. web-browser interfaces), which communicates with our web server in order to visualize our customized XML repository contents. The retrieved digital content is then rendered with the aid of XSL stylesheets (visualization templates) initially on the web browser and then on the AR tabletop environment.

To test the functionality of the web-client as a virtual museum, we have prepared some simple virtual museum exhibitions based on content from the Sussex Archaeological Society [23]. Figure 2 shows two web page visualizations (part of a two different virtual museums) that presents information about virtual artifacts. The web pages show a thumbnail and associated metadata and information that describes the artifact. The artifact is also publicized as a 3D object in the centre of the web page (using a VRML client embedded in the web page) and can be manipulated using an input device such as an ordinary mouse or a more advanced interaction device (see section 5)—this extends the typical museum catalogue type interface into 3d rather than just images. Finally, there is an AR link on the web page in the centre above the 3D object which when pressed launches the AR application and in effects displays the 3D object in the users physical world space.

Figure 2: Web3D interactive presentations

By changing content and presentation style using different XSL stylesheets the visualization can be altered in a number of different ways [21], and this can be seen from the two interactive presentation shown.

4.2. A Virtual Environment Example

The EPOCH visualization interface (EVI) is an example of an interactive virtual environment that contains several elements: an input device for aiding interaction, a virtual reconstruction of the museums artifact together with other multimedia rich information, all embedded in a Web3D domain. The end user (a museum visitor) can load different 3D models of the museum artifact and interact with them in numerous ways. Interaction is done through the use of different input devices (as depicted in Figure 1) such as the SpaceMouse, game pad or the Kromstaff replica. The Kromstaff replica is a specially constructed input interface with an embedded orientation tracker and touch sensors that allows the user to explore the virtual artifact. The visualization engine of the EVI utilizes a Parallel Graphics Cortona VRML client to render in real-time performance the virtual artifact in a virtual environment. The visualization client of the EPOCH multimodal interface is shown in Figure 3.

Figure 3: The EPOCH visualization interface (EVI)

In a museum setting, the museum curator would launch the application from a museum display and load the virtual model of the museum artifact. On loading the virtual model the user would need to select an input device which is connected to the system and interact with the virtual model. The curator can then create a presentation or use a predefined presentation by using the presentation manager.

4.3. An interactive Augmented Reality Example

We have developed two versions of an augmented reality interface, which we call ARIF. The first version is integrated with a much larger system called ARCO and the second version illustrated in Figure 4 is integrated with the multimodal MR interface described here. In Figure 4, we see two scenarios of the AR visualization, the first on the left the user is manipulating a virtual artifact in the real world using natural means (a physical marker card), and the second on the right the user is turning pages in a so called 'Magic Book' [2] to reveal the virtual artifact—this artifact can be supplemented with other information in the real world. As described above, the artifact is first visualized in the Web3D environment and if the user wishes to use the interactive AR environment they simply press the 'AR button' on the web page, then the communication sub-system transfers all the appropriate information from the Web3D page into the AR environment and creates a log file in XML format. The AR viewer is then launched, which parses dynamically the XML file and displays the results in the AR client.

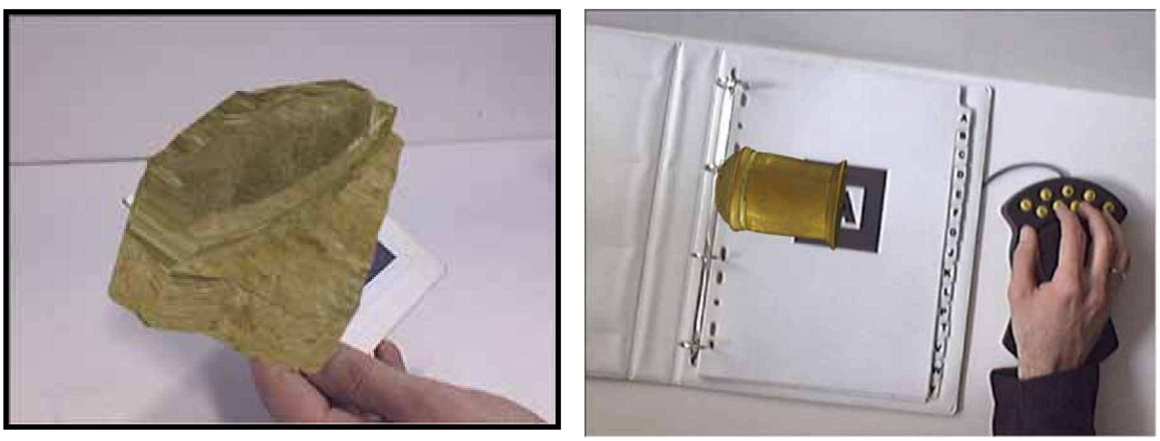

Figure 4: Augmented reality interface

5. DIGITAL HERITAGE INTERACTION

The use of Web3D technologies, with the integration of VR and AR provide a compelling set of technologies with which to a build museum interactive. The addition of multimodal input interfaces to Web3D, VR and AR take this interesting interactive visualisation even further for the benefit of the user. Figure 1 illustrates several potential input devices useful for interacting with the museums digital heritage collections ranging from standard input devices such as the keyboard and mouse, joystick through to bespoke replicas complete with tracking and sensor electronics.

5.1. Interaction with Standard Input Devices

Interaction with a digital heritage content displayed in the visualization interface includes the use of standard I/O devices such as the keyboard and the mouse. Another cheap input device that satisfies the user requirement discuss above is to integrate a normal gamepad (or joystick). This provides an easy to use input device in comparison with the other input devices because many more users, e.g. children, are familiar with this type of input device. Further, an interesting development is the new types of gamepad input device that comes with the Sony PlayStation 3 and the Wii game consoles. These gamepads are both wireless and include motion trackers, which can be used to manipulate and navigate the virtual heritage environment.

It is comparatively easy to program the buttons of a gamepad to offer desired functionality because each button of the gamepad is fully programmable. As an example, three buttons can be used to enable basic transformations, one button to reset the scene and eight buttons can be used to provide information about the museum artifact. The number of the buttons may vary according to the type of the joystick or game pad used. The joystick interface we developed in our interaction interface is shown in the Figure 5 below.

Figure 5: The joystick interface

5.2. Interaction with Complex Input Devices

To make our system more generic and flexible we have supported several more complex input devices that include various useful sensors These sensor devices allow the virtual museum to enhance its presentations and provide better interaction for the visitor.

SpaceMouse

Fulfilling user requirements associated with interaction involves examining several cheaper input device options including the SpaceMouse interface. With the SpaceMouse we can assign functionality (e.g. rotation of the virtual artifact using the SpaceMouse puck, and rich multimedia content to the SpaceMouse buttons, etc.). Thus, we can create a customized nine button-menu interface. Parameters that have been implemented and assigned to the menu buttons include either standard graphics transformations for easier manipulation, or more advanced graphics operations. The SpaceMouse interface is shown in the Figure 6.

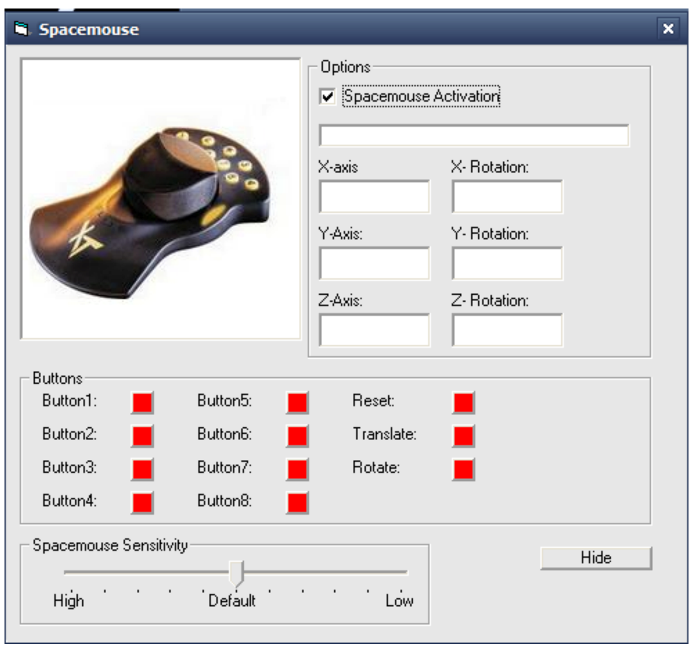

Figure 6: The SpaceMouse Interface

One of the most significant problems of the SpaceMouse occurs when the user is performing translation or rotation operation. It is difficult to intuitively rotate accurately on one axis using the puck because the puck senses micro-movement components on the other axis, thus when the user tries to keep a rotation only on the one axis another axis is still affected. There are two solutions to this: first, the user can set the sensitivity of the mouse according to user preferences. An alternative solution for more accurate rotations is to use the button menu of the SpaceMouse to activate only one degree of rotation at a time. In this case, the axis is being chosen automatically according to the number of button pressed.

Black Box

The SpaceMouse does not provide a really intuitive method for rotation freely about all axes the virtual artifact, however it is very cheap. An improved method, but relatively expensive is to use an orientation tracking device such as the Inertia Cube 2. We built a so called 'Black Box' to test this method and included buttons to allow selection of other functionality, see Figure 7 .

Figure 7: The BlackBox Interface

The user simply holds the BlackBox interface and rotates it in their hands, upon which the virtual artifact is slaved to these rotations and the user sees the virtual artifact turn. The user can thus examine the virtual artifact in the round, and using the buttons can activate other functionality such as zooming in and out, or displaying other information in the Web3D or virtual environment. The same electronics from the black box interface were used to develop the so called Kromstaff interface, which is discussed in more detail in the following section.

Kromstaff Replica Interface

The Kromstaff replica interface utilizes the same electronics as the black box interface, only this time they are embedded in a physical replica or scaled up copy of an 11th century carved ivory top of an abbot's crook currently on display in Museum of ENAME [17, 18, 22, 24, 25]. The replica serves as a physical interface between the object and a virtual model implemented in VRML as part of a Web3D based presentation of the object [17, 18, 22, 24, 25] is shown in Figure 8**Error! Reference source not found.**. The design process of the Kromstaff replica can be broken down into two parts. The first part deals with the construction of the replica itself and the second part deals with the creation of the software that drives the Kromstaff input device. The original artifact was digitized by using a laser scanner and then by using Fused Deposition modeling techniques, the replica was created [17, 18, 22, 24, 25].

Figure 8: The Kromstaff Replica

The second part deals with the creation of software that drives the interface. Initially the user has to activate the Kromstaff presentation interface, and then to select a presentation from the presentation menu, which is shown in Figure 9**Error! Reference source not found.**.

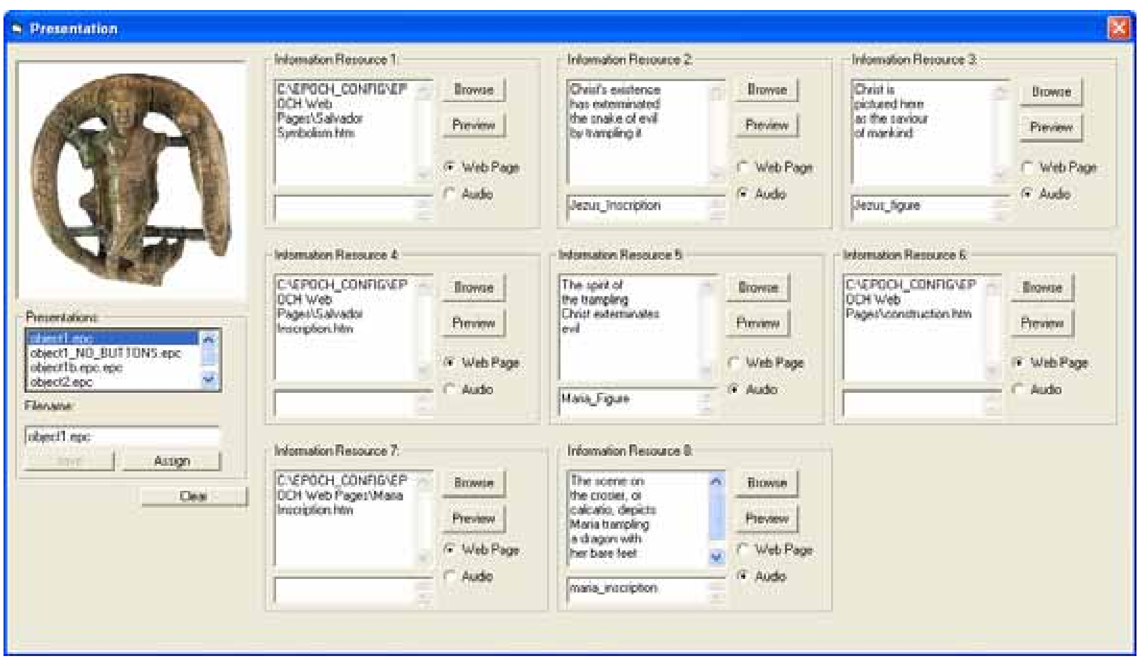

Figure 9: The EPOCH Presentation Interface

6. A WEB3D INTERACTIVE VISUALISATION

Another appealing way for visitors to interact with virtual tours is through interactive 3D galleries where we implement the virtual gallery space in a VRML client that communicates with the Web3D environments (or elements on the web page). Figure 10 illustrates a virtual exhibition presenting museum artifacts in a 3D room or reconstruction of a real gallery—in this case an exhibition gallery in the Victoria and Albert Museum in London [26]. Using this interaction method, visitors can browse virtual objects simply by walking along the room and can retrieve more detailed information using interaction elements integrated into object stands. The visitor interacts with the virtual gallery by dragging and dropping artifacts, movies and textures into the virtual exhibition from the dynamically generated content displayed on either side of the virtual galley—all embedded on the web page. After dragging the objects into the scene the user can translate the objects anywhere into the virtual environment. This virtual museum mixes Web3D, with virtual environments and Web3D based interactions.

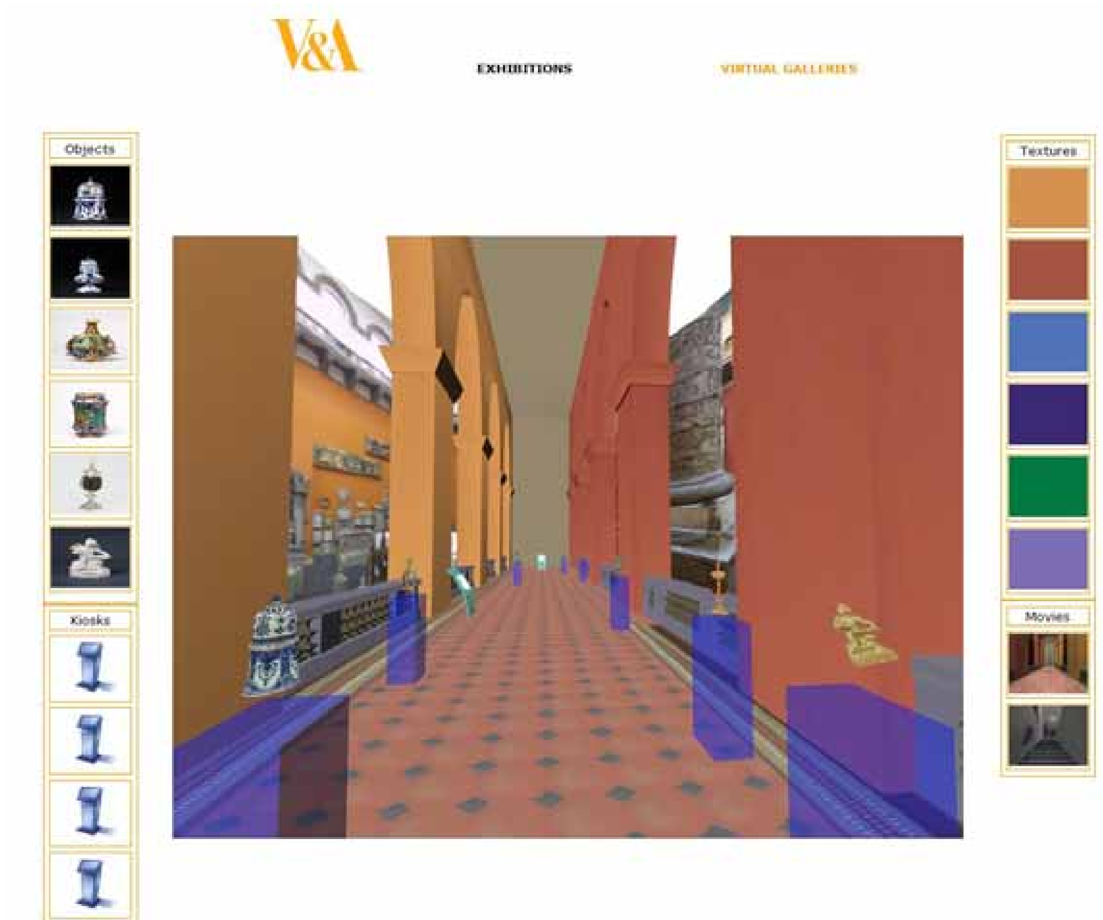

Figure 10: A web based interactive 3D Gallery

7. CONCLUSIONS AND FUTURE WORK

This paper proposes an innovative framework for a multimodal MR interface that contains three rendering modes: an AR; a VR and a web3D. These environments can be used to design effective MR heritage environments. Participants of the system can dynamically switch rendering modes to achieve the best possible visualization. The capability of dynamic switching between cyber and MR worlds allows remote users to bring VR and AR worlds into their own environment. In addition, participants can change dynamically interaction modes to interact with the virtual information in a number of different ways including standard input, sensor, menu and tangible [1].

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